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DUNE STABILIZATION WITH
VEGETATION ON THE OUTER BANKS
OF NORTH CAROLINA

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ABSTRACT

Experiments at the shore and in the nursery were conducted to develop an accelerated and more effective revegetation program on beach and dune areas. Four grasses show promise: American beachgrass, sea oats, dune panic grass, and saltmeadow cordgrass. Pandomized blocks of plantings, with at least three replications, were used in the experiments. Comparison of various methods of producing nursery stock, transplanting at the shore, and fertilization produced positive results shown in figures, tables and photographs. The most practical and economical methods for each step of the program are suggested.

American Beachgrass is best planted between 1 November and 1 April. Plants, of 3 to 5 stems, dipped in a clay slurry, are spaced 18 inches by 18 inches by a machine planter. Depth of planting is 6 to 8 inches. Such a planting, properly fertilized, was used in dune "growing". Fifteen months after planting, a strip 100 feet wide had accumulated 16 cubic yards of sand per running foot of beach. Experiments are being continued.

FOREWORD

Dunes serve as an effective barrier between the sea and low shore areas. They also serve as a storehouse for windblown sand, and release this material to the beach during severe storms. An important feature of the program at CERC is to collect data that will help coastal engineers stabilize existing dunes or build artificial dunes as protective structures. CERC is publishing this paper in order to give a wider dissemination to this significant information about dune "growing".

This paper was prepared by Professor W. W. Woodhouse, Jr. and R. E. Hanes (a research instructor) of the Department of Soil Sciences, North Carolina State University, Raleigh, North Carolina.

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The cooperation of the staff of the Cape Hatteras National Seashore over the past five years is especially appreciated. Without their facilities, funds and personnel, this work could not have been accomplished.

At the time of publication J. M. Caldwell was Acting Director of the Coastal Engineering Research Center.

NOTE: Comments on this publication are invited. Discussion will be published in the next issue of the CLERC Bulletin.

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DUNE STABILIZATION WITH VEGETATION ON THE OUTER BANKS OF NORTH CAROLINA

by

W. W. Woodhouse, Jr. and R. E. Hanes

I. INTRODUCTION

North Carolina has over 250 miles of Atlantic coastline essentially made up of a chain of low, sandy, barrier islands. These are separated from the mainland only by marshland at some points, but by as much as 30 miles of open water at others. The preservation of these Outer Banks is important to the State and the nation not only for their recreational values, but for the protection from the open sea their presence affords the mainland.

While there is little likelihood that these islands will disappear in the foreseeable future, wind and water erosion, accelerated by man's activities and a recent series of severe storms, has brought about a rather critical situation on many parts of the Banks. Large stretches have been reduced to essentially bare sand flats with elevations of only 4 or 5 feet above mean sea level.

The original purpose of this investigation was to make possible an accelerated and more effective revegetation program on the beach and dune areas with a view to protecting the low areas. Work the first two years was concentrated primarily on fertilizer trials on the Banks, utilizing stands that already existed. In 1963, in cooperation with North Carolina Forestry Division, steps were taken to develop a supply of planting stock suitable for experimental plantings. With the availability of additional funds, trials have been expanded to include a number of different phases of the revegetation process. While many of the results are quite preliminary in nature, publication at this time is desirable to provide acutely needed factual information for planning and carrying out sound programs of revegetation in this region.

Until very recently studies on the propagation and growth of the dune grasses in this country have been confined largely to the West Coast (4)*. Attention there and in Northern Europe has been concentrated primarily on European beachgrass, *Ammophila arenaria*, a species not very well adapted to the Atlantic Coast.

Planting of the dune grasses has been going on along the East Coast for some time (3) (5). Recently, studies have been initiated at several points to obtain information that would be more applicable to these conditions (6) (10) (11).

* Numbers shown in this manner refer to LITERATURE CITED on page 45.

2. MATERIALS AND METHODS

a. Estimating Growth Responses

Most of the experiments initiated from 1961 to 1963 utilized stands of American beachgrass, *Ammophila breviligulata*, and saltmeadow cordgrass, *Spartina patens*, already established; some natural, but most of them planted by the National Park Service from 1 to 3 years prior to 1961 on Ocracoke, Bodie and Hatteras Islands. These stands tended to be much more variable than would be desirable for field plot purposes, resulting in quite variable data.

Since sand trapping was considered a major function of the cover produced, it was not deemed desirable to harvest the growth to measure treatment effects. Consequently, we were faced immediately with the problem of devising a suitable technique that would measure field responses under these limitations. A considerable amount of time was devoted to counting stems; estimating heights of stems, perimeter of clones, and various combinations of these. It soon became apparent that American beachgrass, as it normally occurs both on the dunes and in the nursery, is a mixture of types having a wide range in stem size and length. Also, individual clones, due to variations in age and environment, produce stems that vary considerably in their dimensions. Of greater concern was the fact that a single plant, under suitable conditions, can produce 50 to 100 stems in one season, making stem counting a very laborious task. Cordgrass is even worse in this respect. This experience led to the conclusion that data based on stem counts was not too reliable and was much too expensive.

Fortunately, in the summer of 1962, a device was developed which estimated bulk (dry weight) of grass in rows by measuring resistance to compression (10). This procedure was found to be quite rapid and accurate for American beachgrass and saltmeadow cordgrass as long as the plants remained in rows. However, under favorable treatment, new plants soon appeared between rows and by the summer of 1964, a method which would handle broadcast stands became necessary. This was done by modifying a method, based on resistance to vertical compression, developed for use on forage plants (1). The modified method consists of dropping a reinforced sheet of aluminum (2 x 2 feet) over the grass, and measuring the average height the square remains above the ground. These data are then converted to pounds per acre by the formula:

$$(h^2) (c) = \text{lb/acre dry weight}$$

where h = average height and c is an appropriate constant developed for each species. The method is rapid and reasonably accurate, yielding correlation coefficients of 0.90 or better on stands of American beachgrass, saltmeadow cordgrass and dune panic grass. It is not satisfactory on sea oats after the large seed stalks on this species have fully emerged.

b. Field Plot Technique

Essentially all of the experiments have been in randomized blocks with at least three replications. Plot size and shape varied considerably

at the beginning, but after some trial and error, a minimum size of 8 x 50 feet was adopted. Much larger plots were used where the purpose was primarily demonstrational.

Since the beach is the primary source of blowing sand in these areas, it has been found essential that the long dimension of the individual plot be oriented perpendicular to the shoreline to avoid large amounts of uncontrolled variation due to sand accumulation.

Border effects from the application of standard fertilizer materials are surprisingly small in view of the extremely windy conditions prevailing. On three-year-old plots, this effect has quite obviously been confined to a strip about 24 to 30 inches wide around each plot. Apparently, the fertilizer materials, being hygroscopic, soon stick to the sand particles and do not move thereafter unless the sand moves. Normally, there is little or no movement by either wind or water from within well-vegetated areas. It has been found advisable to use pelleted or granular materials since it is almost impossible to apply dusty fertilizer without some blowing.

c. Fertilizer Materials

Ammonium nitrate, concentrated superphosphate, and muriate of potash were used as the standard sources of Nitrogen (N), Phosphorus (P), and Potassium (K), respectively. The normal method of application of these materials was to broadcast them on the surface, either by hand or with a small spreader.

3. DUNE AND BEACH PLANTS

Attention in this study, to date, has been confined primarily to the most critical areas along the Banks, generally a zone extending 500 to 600 feet back from the high tide mark with an elevation of only 4 to 6 feet above mean sea level except for the foredune, where it exists, which may be as high as 12 to 14 feet above mean sea level.

It has not yet been convenient to make any very direct comparisons between species. However, during the past five years, observations have been made as to the adaptation and behavior of the plants that are present in the area.

Perennial grasses are the only plants in this zone that appear to make a substantial contribution in trapping and binding sand. Some annuals, especially sea rocket, *Cakile edentula*, and beach pea, *Strophostyles levoia*, are temporarily effective. Other annuals and perennials invade and help to cover areas that have first been fairly well stabilized by perennial grasses. Frequent exposure to salt spray results from the generally low elevation and absence of large dunes, and appears to be a major factor discouraging the woody plants, such as yaupon, myrtle, silverling, live oak and red cedar.

At present, there are four grasses growing on the Banks which appear to show real promise in this critical zone. These are American beachgrass

(*Ammophila breviligulata*), sea oats (*Uniola paniculata*), Dune panic grass (*Panicum amarum*) and saltmeadow cordgrass (*Spartina patens*).

a. American Beachgrass (*Ammophila breviligulata*)

American beachgrass is the only one of these grasses of which ample planting stock is presently available and the only one that has been planted extensively on the foredune portions of the Banks. So far, this species appears to be an excellent grass for this purpose. It lends itself quite well to nursery propagation, can be transplanted to the Banks with almost perfect survival, grows off quite rapidly following transplanting and is capable of trapping and coming through large quantities of sand. Being indigenous to the Atlantic coast, north of the Virginia Capes, it is not as tolerant of hot, dry weather as sea oats and dune panic grass, but has done quite well on fairly high dunes as far south as Bogue Banks, and in trial plantings at lower elevations to the South Carolina line.

American beachgrass is quite tolerant to salt spray and will withstand occasional flooding by salt water in cool weather. During the hot summer period, it is killed quite readily by salt tides. Some disease and insect damage has been observed on this species, but so far, nothing of this kind has reached serious proportions.

Under favorable conditions, American beachgrass spreads readily through the production of extensive rhizomes. Some reproduction from seeds occurs but this is sporadic and does not appear to be very extensive.

This grass can tolerate and continue to grow through rather rapid sand accumulation. One example of this capacity is illustrated in Figure 1. Under the rapid rate of accumulation shown, most plants were completely covered at one time or another and there appeared to be some thinning of stands at all sites. However, on the last day (October 20, 1965), an adequate stand remained at most points with some 6 to 8 inches of grass protruding above the sand (see Figure 2). New roots had developed to within 6 to 8 inches of the surface with the original root system still viable. A great deal remains to be determined on this point, but it is apparent that American beachgrass is capable of withstanding very substantial sand accumulation during the growing season.

b. The Sea Oat (*Uniola paniculata*)

The sea oat is widely distributed from the Virginia Capes to Mexico. On the North Carolina coast, this grass is the principal occupant of unplanted dunes near the sea. It is an excellent sand catcher. Unfortunately, natural stands are frequently sparse, resulting in rapid accumulation of sand by the individual plants and the growth of rough, hummocky dunes. This characteristic has given rise to the belief that this grass always forms rough dunes. However, where good stands have been observed, there seems to be little difference between a sea oat dune and an American beachgrass dune.

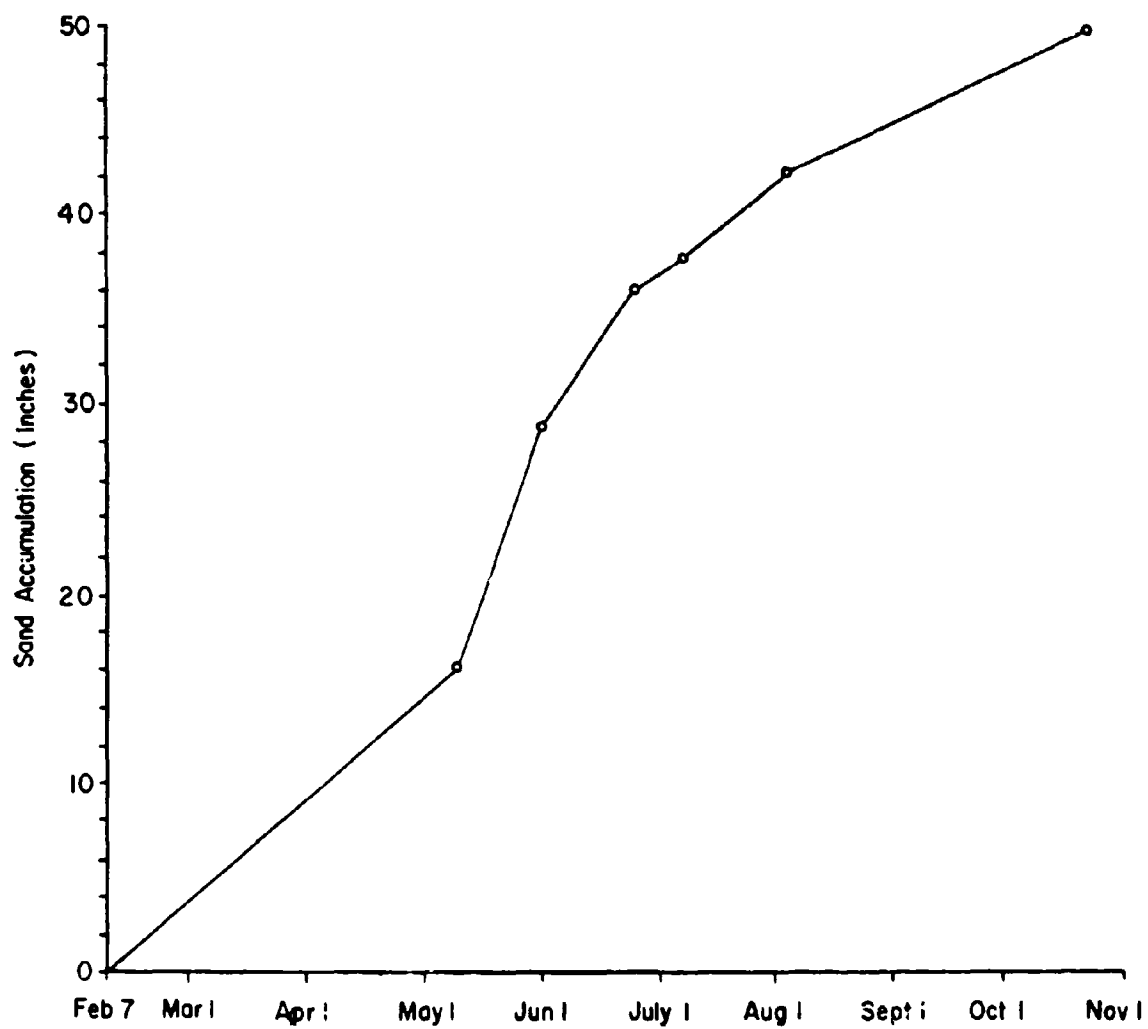


Figure 1 Rate of Accumulation of Windblown Sand on American Beachgrass Planting - Ocracoke Island, February 1965 - Average of two sites.



Figure 2. American Beachgrass, on Which Sand Accumulation is Charted in Figure 1. Photo taken October 20, 1965.

Where the sea oat and American beachgrass occur together on a foredune, the sea oat will usually occupy the "front line" nearest the surf. We are inclined to interpret this as being due in part to a higher tolerance to salt water on the part of the sea oat, particularly during the warm part of the year.

This grass has not been planted extensively due largely to (1) the absence of supplies of planting stock, and (2) the poor survival that usually follows transplanting of plants dug on the Banks. It would probably be desirable for it to be more widely used, but it appears that such use will have to await the development of better propagation procedures.

The sea oat does produce fairly heavy crops of seed in some years and under favorable conditions, large numbers of these seed germinate all along the Banks. This occurs in late spring and since growth is quite slow during the first year, most plants are not firmly established until near the end of the second growing season. As a result, percent survival of the original seedlings is extremely low. Even so, the natural spread of this species into unoccupied areas along the Banks seems to be accomplished almost exclusively in this way.

c. Dune Panic Grass (*Panicum Amarum*)

Dune panic grass is distributed naturally all along the Banks and seems to be on the increase since livestock have been excluded from these areas. This grass is a good dune builder, having an extensive rhizome system and stiff stems and leaves, but may not be quite as tolerant of salt spray as American beachgrass and sea oats. It can be multiplied readily under nursery conditions, but starts off much slower than American beachgrass when transplanted to the dunes. It certainly shows promise, but more work with it is needed, particularly on planting methods, before it can be suggested for extensive use.

d. Saltmeadow Cordgrass (*Spartina patens*)

Saltmeadow cordgrass probably represents the largest acreage of any plant on the Banks, being the principal grass on the flats and low dunes behind the foredune. Tolerant to salt water and a high water table, it is well adapted to the low-lying areas. This species transplants readily, and also spreads naturally by seed. It will withstand only a fairly slow buildup of sand, is not very drought-tolerant, and consequently should not be planted where sand movement is rapid or on dunes of appreciable height.

e. Species for Traffic Areas

None of the foregoing grasses is really suitable for use on sites receiving heavy traffic. A turf type grass is needed for such areas as campgrounds, around parking areas, and walkways. The two principal species of this kind found in the area at present are Bermuda grass (*Cynodon dactylon*) and knotgrass (*Paspalum vaginatum*). Bermuda grass was used in stabilizing

the Wright Brothers Memorial; It is found on flats and around buildings. Knotgrass occurs on the poorly drained flats and moist road shoulders.

The Bermudas will tolerate a considerable amount of salt either as spray or in the soil and a moderate rate of sand buildup. Observations indicate that these plants require at least as much, if not more, nitrogen than the dune grasses to maintain them in a healthy condition. They should be sprigged in early spring in order to insure establishment before excessive drying of the sand occurs. Planting can be done satisfactorily up to early summer where irrigation is available.

4. FERTILIZATION

a. Response to Fertilizer

The only species of which stands were available for the preliminary trials in the spring of 1961 were American beachgrass, *Ammophila breviligulata* and saltmeadow cordgrass, *Spartina patens*. The former was located largely on the dunes and the latter on the sand flats and low dunes. The first treatments were applied in March 1961. As mentioned earlier, no usable data were taken that summer due to the lack of a suitable technique. It was possible to observe some response, particularly to nitrogen (N); plants were greener and growth increased 50 percent to perhaps 100 percent. The overall effect was disappointing in light of the very poor growth of untreated areas. Doubling this very sparse growth still left the cover inadequate.

Other trials were then established in September 1961 and as soon as new growth was initiated in the spring of 1962, it appeared that the fall fertilization had improved the situation materially. Fortunately, although a number of trials were lost in the March 1962 storm, the two reported in Tables 1 and 2 were not seriously damaged.

TABLE 1

Growth Response of American Beachgrass to Fertilizers - Hatteras Island

Plot No.	Treatments				P ₂ O ₅ lb/acre	K ₂ O lb/acre	Yield, lb/acre (dry weight)			
	Nitrogen, lb/acre						1962	1963	1964	1965
	Apr	Jun	Aug	Sep						
1.	--	--	--	--	--	--	341	216	896	104
2.	33	33	33	50	--	--	2557	2871	6781	5570
3.	33	33	33	50	50	--	2871	3172	6458	5698
4.	33	33	33	50	50	50	2359	3575	5593	5554
Least Significant Difference - .05										340
Least Significant Difference - .01										516
Coefficient of Variability -										28%

TABLE 2

Growth Response of Saltmeadow Cordgrass to Fertilizers - Ocracoke Island

Plot No.	Treatments						Yield, lb/acre (dry weight)			
	Nitrogen, lb/acre				P ₂ O ₅ lb/acre	K ₂ O lb/acre	1962	1963	1964	1965
	Apr	Jun	Aug	Sep						
1.	--	--	--	--	--	--	454	604	757	608
2.	33	33	33	50	--	--	2030	4047	6675	6594
3.	33	33	33	50	50	--	2757	3858	7055	7426
4.	33	33	33	50	50	50	2842	4161	5942	5994
Least Significant Difference - .05										1559
Least Significant Difference - .01										2186
Coefficient of Variability -										38%

Both experiments, one on American beachgrass and the other on cordgrass, were on stands that had been established 1½ to 2 years earlier.

In both of these experiments, the response to nitrogen (N) was very pronounced and was of the same general order. There appeared to be some indication of a benefit from the application of phosphorus (P) the first year with this being questionable in later years. The addition of potassium (K) was of doubtful value throughout. Growth on the nitrogen and nitrogen-phosphorus treatments seemed to reach a maximum by the third year on both species.

These are the only experiments in this study that have been carried through four full growing seasons. The data seem to indicate that maximum cover can be produced under this kind of fertilization regime in two to three years.

The pattern exhibited in these experiments is fairly representative of the results of most tests conducted so far. Nitrogen is the principal limiting factor, with perhaps some response to phosphorus and none to potassium. However, there have been a few locations where the application of phosphorus was definitely beneficial. Two of these locations are shown in Tables 3 and 4.

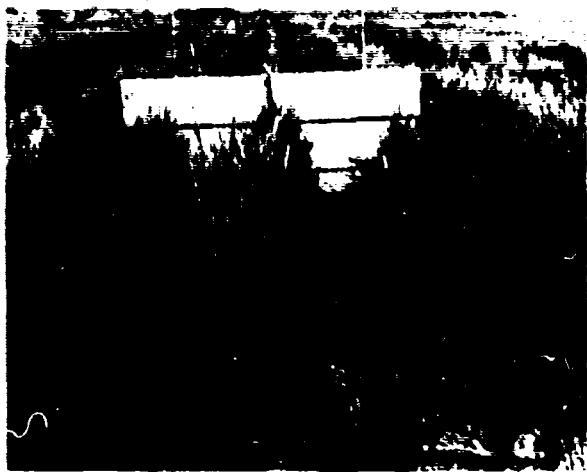


Figure 3. Fertilized American Beachgrass, 11 Months After Fertilization was Initiated, Hatteras Island.



Figure 4. Unfertilized American Beachgrass on a Check Plot Adjacent to Figure 3 - Hatteras Island



Figure 5. Saltmeadow Cordgrass - Unfertilized in Foreground - Fertilized in Background, 11 Months after Fertilization Began - Broadleaved Plant is Pennywort - Ocracoke Island

TABLE 3

Response of American Beachgrass to Phosphorus - Hatteras Island

	<u>Treatment lb/acre</u>				<u>Yield, lb/acre (dry weight)</u>	
	Apr	Jun	Aug	Sep	<u>1962</u>	<u>1963</u>
Check					406	302
N	33	33	33	33	1273	1505
NP	33	33	33	33	1580	2115
	(plus 50 lb P ₂ O ₅ in April)					

TABLE 4

Response of Saltmeadow Cordgrass to Phosphorus - Ocracoke Island

(Fertilization Initiated Fall of 1963)

<u>Treatment</u>					<u>Yield, lb/acre (dry weight)</u>
<u>N lb/acre</u>		<u>P₂O₅ lb/acre</u>	<u>K₂O lb/acre</u>		
May	Jul	Sep			
--	--	--	--	--	2,431
33	33	50	--	--	5,984
33	33	50	50	--	10,125
33	33	50	50	50	9,339

The American beachgrass site is on a dune which probably has received some fresh sand in recent years. The cordgrass is on a flat some distance from the beach where there was much less likelihood of sand accumulation, and probably represents sand that has been in place and subject to weathering for some years.

The data in Table 5 are from an experiment initiated in the spring of 1965 and show first-year response of freshly planted American beachgrass. This table shows the same type of response found in earlier experiments but the magnitude of response on newly planted material was much lower. This is probably partly due to the fact that the planting stock used was well fertilized in the nursery, and therefore, contained good levels of these nutrients when transplanted. It does show that fertilization the first season after planting is beneficial.

TABLE 5

Response of American Beachgrass to Nitrogen, Phosphorus and Potassium

	<u>Treatment lb/acre</u>				<u>Yield, lb/acre 1965</u>
	Apr	Jun	Aug	Sep	
Check	None				465
N	33	33	33	33	757
NP	N 33	33	33	33	962
	P 75				
NPK	N 33	33	33	33	961
	P 75				
	K 75				
NP (30-10-0)	111	111	111	111	919
Least Significant Difference - .05					287
Coefficient of Variability -					52%

b. Time and Rate of Application of Nitrogen

From the observations made on several preliminary tests, initiated in 1961, it appeared that these grasses benefited from at least 100 to 150 pounds of nitrogen per acre per year. There were also indications that this amount should be split into three or four applications. The September treatment appeared to be particularly important from the standpoint of rhizome production the following spring.

Unfortunately, no usable data were obtained from these trials due to the lack of a suitable method in 1961 and to storm damage and unequal sand encroachment in 1962 and 1963.

We do know that growth response to the rates and timing of nitrogen application adopted on the strength of these very preliminary trials has been quite satisfactory. It is very likely that with further experimentation, modifications and refinements will be found to be desirable. Data from the two trials on seasonal distribution of growth and nutrient uptake (figures 6, 7 and 8) suggest that the rates indicated above are not unreasonable and could probably be stepped up somewhat where maximum growth is desired.

Since other questions seemed more pressing in 1964, new trials needed to provide specific information on these points were not undertaken until 1965.

Consequently, data will not be available on rate and time of fertilizer application until the end of the 1966 season.

c. Source of Nitrogen

Three experiments involving nitrogen sources were initiated in the spring of 1964. Two of these were on plantings of American beachgrass on a fore-dune and saltmeadow cordgrass on the Ocracoke flats that had been made 4 or 5 years earlier. The third, American beachgrass on hydraulic fill, utilized a stand planted in March 1964. Treatments began in April 1964 and growth measurements were made in August 1965. These data, shown in Table 6, indicate that all of the standard soluble sources, applied in the normal manner, were equally satisfactory over the fairly wide range of conditions represented by these trials. The Urea-Formaldehyde form, applied on the surface, was substantially less effective than the readily soluble forms. Due to the low moisture holding capacity and very low microbial activity of these sands, it will probably be necessary to incorporate the less soluble forms with the sand in order to make it a fair test. Such a test is to be tried in 1966.

TABLE 6

Source of Nitrogen on Dune Grasses - Initiated Spring 1964

<u>Source</u>	<u>Yield (1965) lb/acre dry weight</u>		
	<u>Beachgrass</u>		<u>Cordgrass</u>
	<u>Foredune*</u>	<u>Hydraulic fill**</u>	<u>Ocracoke flat*</u>
1. Check	983	391	294
2. Ammonium Nitrate	5935	4428	5492
3. Ammonium Sulfate	5349	--	6380
4. Urea	5145	4673	5492
5. Sodium Nitrate	5670	4618	5889
6. Urea-Formaldehyde	3258	2365	2197
7. 30-10-0	5681	5058	6122
Least Significant Difference .05	1365	1046	1379
Least Significant Difference .01	1858	1641	1875
Coefficient Variability	45%	25%	47%

*4 replications; **2 replications

All plots received annually 50 pounds Nitrogen, April, June, August, plus 50 pounds P₂O₅ and K₂O in April, except 30-10-0 plots

d. Maintenance Fertilization

It is evident at quite a number of locations that a fertilizer program consisting of 100 to 150 pounds of Nitrogen and 30 to 50 pounds P_2O_5 /acre/year will develop "full cover" by the end of the third growing season. The term "full cover" is used here to mean something approaching the maximum amount of growth of these grasses that these areas seem to be capable of supporting, i.e., of the order of $2\frac{1}{2}$ to $3\frac{1}{2}$ tons/acre dry weight. In a number of cases where vigorous nursery stock of American beachgrass was used, something approaching full cover was attained with only two growing seasons.

It also appears that any attempt to push growth beyond this point may have some detrimental effects. For example, in the trials reported in Tables 1 and 2, and on several areas under the general Park Service fertilizer program, some loss of plants has occurred. This loss has taken place largely during the summer of 1965, a very wet summer, and in spots where growth was unusually dense. The cause of death in several instances is strongly suspected to be the common fungus, *Rhizoctonia solani*. This loss is not surprising, for this organism is a frequent source of damage to a wide range of host plants, both grasses and legumes, during periods of hot humid weather. Such damage is usually increased by heavy matted growth which limits air circulation and normal drying, and is aggravated on cool season grasses by nitrogen applications made during the hot weather period.

For this reason, and economy, it seems highly desirable to switch to a program of reduced fertilization once full cover is attained. Presumably, maintenance would require less frequent and smaller applications of fertilizer than were required to bring the stand to the full cover stage. Under the fairly complete canopy prevailing at this stage, there should be considerable recycling of nutrients. Unfortunately, sufficient areas having growth of this kind have not been available long enough to permit much experimentation on this point. Beginning after the September application in 1964, some sub-plots have been laid out from which fertilizer has been omitted. Growth estimates taken at the end of August on three of these plots are shown in Table 7.

TABLE 7
Effect of Reducing Fertilization on Growth of Beachgrasses

<u>Treatment</u>	<u>Yields lb/acre</u>		
	<u>Beachgrass</u>		<u>Cordgrass</u>
	<u>Oregon Is.</u>	<u>Hatteras Is.</u>	<u>Ocracoke</u>
No fertilizer	1171	301	671
30-10-0 through 1965 (450 lb/acre per year from 1963)	8400	6640	5315
30-10-0 through September 1964	7608	6183	5141

These trials indicate that once full cover is attained, fertilization can be discontinued for one year without incurring any serious decrease in cover. It is much too early to anticipate the second-year effect. Stands from which fertilizer was withheld this year do give the appearance of being nitrogen-deficient and decreasing in vigor. From this, one would suspect that the second-year effect might be more drastic than is suggested by the data in Table 7, and that some fertilizer will be required in alternate years at least, and perhaps every year, in order to maintain vigorous stands. Trials are set up now which should provide, over the next two or three years, a much better basis for establishing a maintenance fertilizer program.

e. Regeneration of Stands

(1) American beachgrass. It is rather generally recognized that stands of American beachgrass often tend to weaken and die out once an area becomes stabilized and new sand ceases to enter it. This has given rise to the idea that the continuing accumulation of sand is essential to the normal growth and survival of this species. This study has shown that this plant does thrive on sand accretion, and can trap and come through quite large quantities of sand during the growing season. However, a large part of the beneficial effect of the accumulating sand must be attributable to an increase in the supply of nutrients (primarily nitrogen) associated in some way with the trapped sand.

One trial, initiated in September 1963 to indirectly test this hypothesis, was located on a large dune situated about one-fourth of a mile from the surf. This area had been planted about 5 years earlier on what had been a "live" dune, and then a strong foredune was constructed between it and the surf. The foredune almost completely stopped sand movement into the area except at a small spot about 100 yards south of the experimental site. The grass in this planting grew slowly for the first year or two, and then gradually began to deteriorate so that by September 1963 less than a 50 percent stand of very stunted plants remained except at the small spot which continued to receive sand. There was a very noticeable revival of growth on the treated plots during the 1964 growing season, and by the summer of 1965, the stand had thickened considerably. Growth measurements taken in August 1965 are shown in Table 8.

TABLE 8

Effect of Fertilizer (Nitrogen, Phosphorus, Potassium) in Reviving
Degenerate Stands of American Beachgrass

<u>Treatment</u>	<u>Growth lb/acre, August 1965</u>
Check - no fertilizer	240
N - 33 lb. N September, April, July (1963)	2129
NP - N as above + 50 lb. P ₂ O ₅	2261
NPK - NP as above + 50 lb. K ₂ O	2521
Least Significant Difference - .05	795
Least Significant Difference - .01	1092
Coefficient Variability	44%

While the stands on these plots are still quite ragged, continued fertilization will probably enable the plants that still remained at the beginning of the test to completely re-cover the area in another year or two. It remains to be seen whether fertilizers alone will produce growth on this site comparable to that which has been developed elsewhere. It is apparent that lack of nutrients was a major factor in the loss of vigor of the grass on this site.

There is some slight hint of a response to potassium on this site, which should not be too surprising in view of the relative inaccessibility to salt spray and new sand as compared with most sites used in this study.

(2) Other grasses. Deteriorating stands of the other species have been observed and the results from trials initiated on these suggest a similar condition as shown below:

TABLE 9

Effect of Fertilization on the Regeneration of Stands
of Sea Oats and Dune Panic Grass

<u>Treatment</u>	<u>Yield lb/acre 1965*</u>	
	<u>Sea Oats</u>	<u>Dune Panic Grass</u>
Unfertilized	1899	1136
30-10-0 100 lb/acre, April June and September	9854	9411

*Initiated April 1964

Data from the same kind of situation with cordgrass are shown in the last column of Table 6.

It appears from these trials that nutrient supply is of prime importance to all four of the principal stabilizing grasses in this area, and that fertilizer alone may be the answer to the stand deterioration that tends to occur as areas become stabilized. It also would seem to follow that fertilization would be less essential on sites receiving large quantities of windblown sand. On the other hand, in situations such as that shown in Figures 1 and 2, a considerable amount of extra growth is required to enable the grass to keep up with the rapid sand encroachment and under such conditions, fertilizer response has been observed repeatedly. For this reason, it appears inadvisable to reduce fertilization appreciably because of sand accumulation.

5. SEASONAL GROWTH AND NUTRIENT UPTAKE - AMERICAN BEACHGRASS

Two experiments were initiated in the spring of 1965 designed to obtain estimates of the seasonal pattern of growth and nutrient uptake in a first-year stand of American beachgrass. One of these was located on

Ocracoke Island on dune sand, and the other was situated on Hatteras Island on hydraulic fill covered by a thin layer of windblown sand. Stands of this grass planted in February 1965 were utilized. The experimental design was a randomized block, 3 replications, with each replicate containing four 20-foot rows for each date of harvest. Each plot was harvested once and only once so that the growth harvested represented the total growth to this date. Harvests were made at intervals of about 2 weeks throughout the season beginning approximately 30 days after the initiation of growth in the spring. The entire harvest sample was dried, weighed, chopped, and subsampled for chemical analysis.

The fertilizer program was designed to maintain fully adequate supplies of nitrogen, phosphorus and potassium throughout the season and was as follows:

	<u>N</u>	<u>P₂O₅</u>	<u>K₂O</u>
March 26 - April 3	60	20	24
May 10-11	40	13 1/3	12
June 23	40	13 1/3	12
August 5-11	<u>40</u>	<u>13 1/3</u>	<u>12</u>
Total	180	60	60

All values given are lb/acre

Data from these experiments are presented in Figures 6 through 8 and Tables 10 and 11. They present a fairly complete picture for this one growing season.

Obviously, it would be preferable to have data of this kind for several years before attempting to draw any hard and fast conclusions. However, since this is the first study of this sort that we are aware of, it seems worthwhile to examine these data and draw such inferences from them as can be justified.

a. Growth

On both Ocracoke and Hatteras the 1965 growing season was rather dry during April and May, quite wet in June, July and early August, and was again dry in September and October. This kind of rainfall pattern might be expected to minimize both leaching and growth in the early part of the season and perhaps promote more than normal growth during the midsummer period. Examination of the data in Figure 6 indicates that the growth rate was rather slow during the first 30 to 40 days of the growing season, but formed very nearly a straight line from that point on until very near the onset of cold weather.

These data certainly show a more rapid rate of growth during a wet midsummer than could be expected during an extremely dry summer. On the other

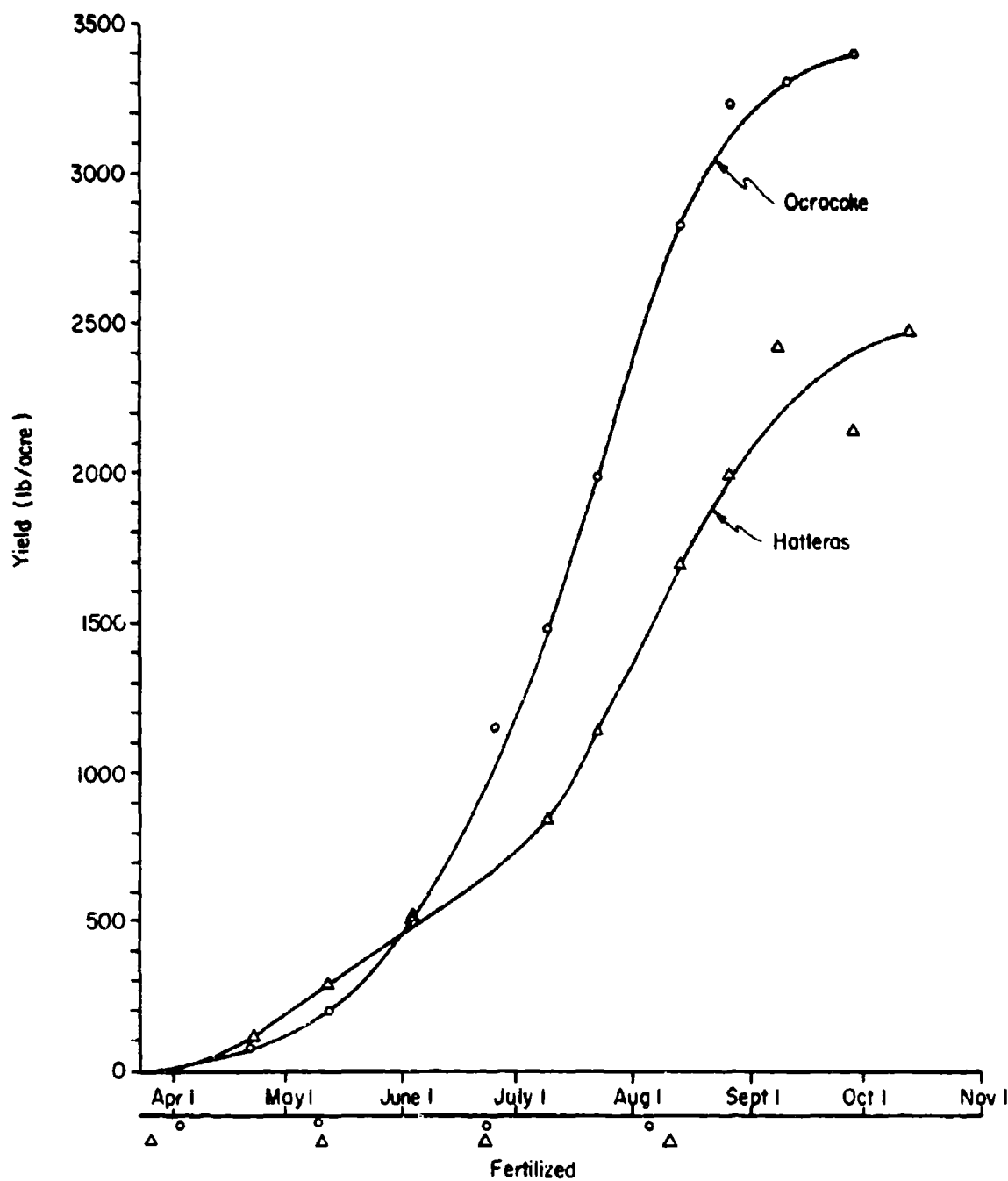


Figure 6. Seasonal Growth Curve - American Beachgrass

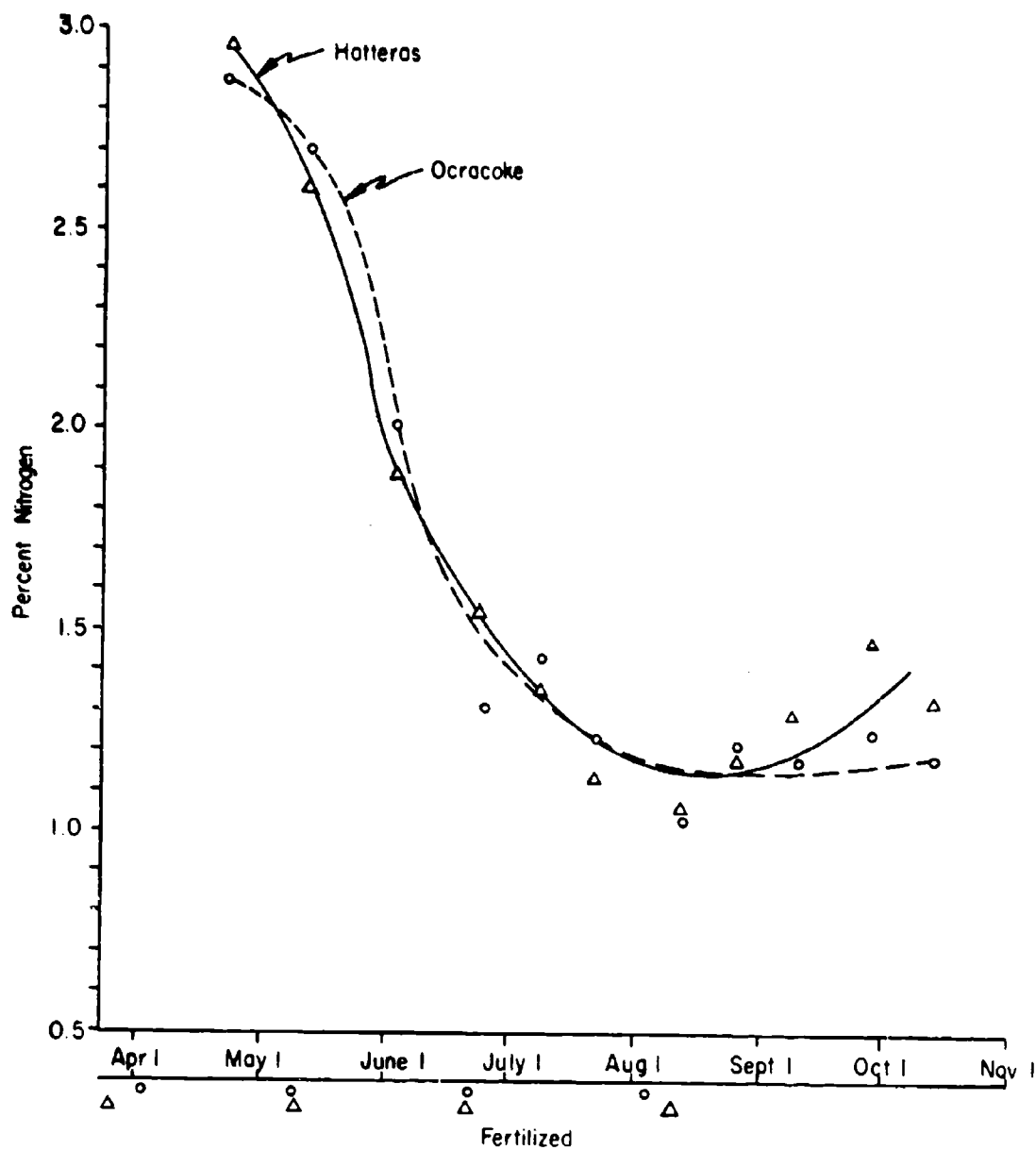


Figure 7. Seasonal Distribution of Nitrogen Concentration

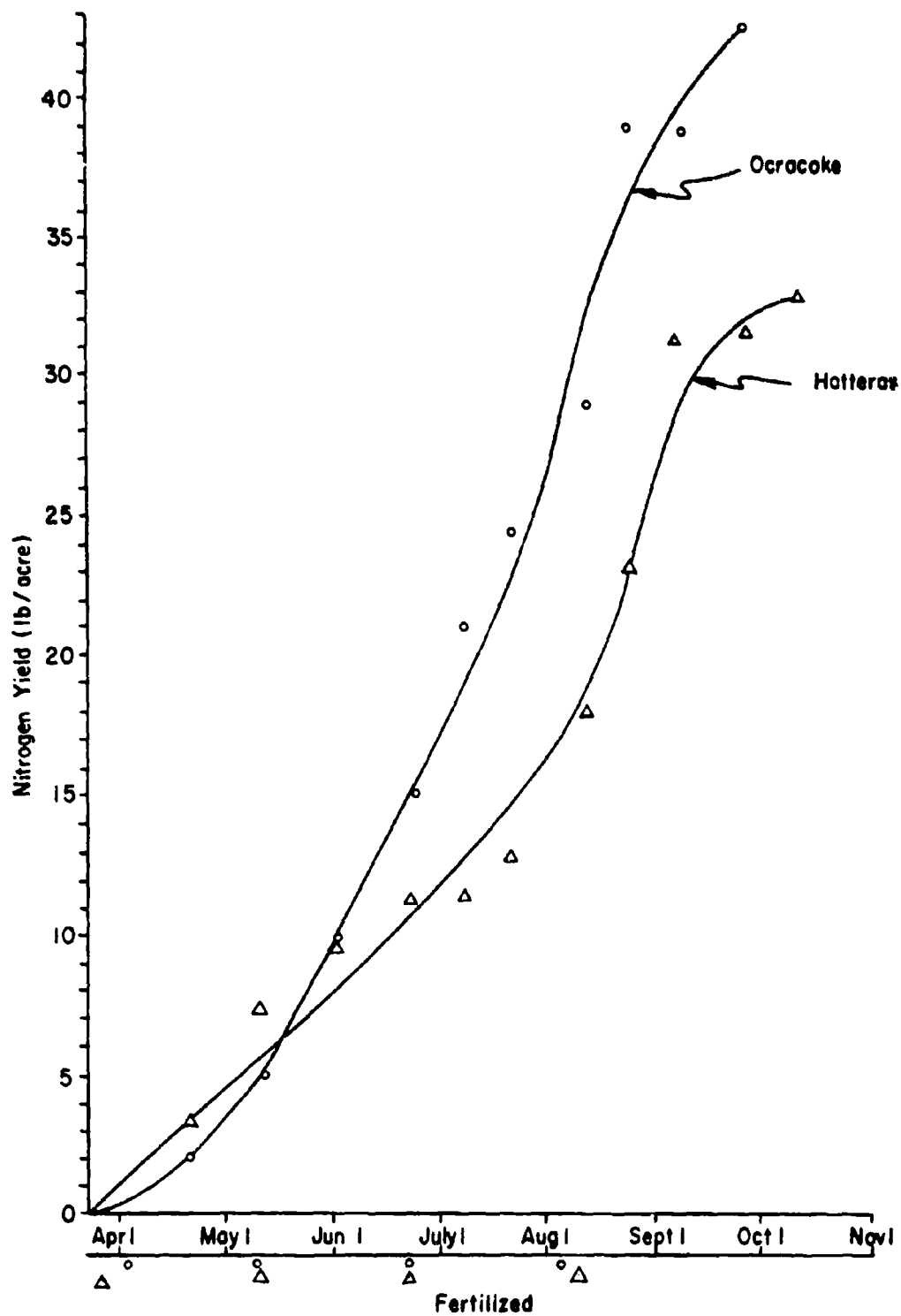


Figure 8. Seasonal Distribution of Nitrogen Uptake
21

hand, they do demonstrate the potential for growth that exists in the species, given adequate moisture and nutrient supplies.

b. Chemical Composition

The data on chemical composition and nutrient uptake from the two experiments are shown in Tables 10 and 11. For most nutrients, there is a tendency, not uncommon in perennial grasses, for the concentration in the plant to decline as the season progresses and maturity approaches. In both experiments, nitrogen, potassium, and to a lesser degree, phosphorus and sulphur, follow this pattern. Nitrogen illustrates this pattern in Figure 7; calcium, magnesium and sodium contents did not appear to form any very consistent seasonal pattern.

c. Nutrient Uptake

Since the concentration of all nutrients in the plant was quite low, except in a few instances very early in the season, dry matter yield largely determined the seasonal distribution of the uptake of nutrients. This results in essentially a straight line from shortly after the initiation of growth until very nearly the end, as illustrated for nitrogen in Figure 8. Such an uptake pattern indicates a continuous need for nutrients throughout the growing season, and tends to support split applications, particularly for nutrients such as nitrogen which may be lost rapidly from these sands.

The amount of nitrogen harvested in the above-ground portion of the plant at the end of the season (42 pounds at the Ocracoke site) is of some significance. If one were to assume a recovery of applied nitrogen of 40 percent, which seems optimistic for these conditions; this would suggest the need for the application of over 100 pounds of nitrogen per acre per year for full growth of American beachgrass the first year.

d. Plant Analyses

In addition to data presented in the previous sections, analyses were made on a limited number of samples collected from eight other sites, one or more of which involved dune panic grass or sea oats. These samples were taken in late June and early July and were from simple replicated tests of an observational nature which had been underway from 1 to 4 years at the time of sampling. The analyses, along with the dry weight production for the 1965 season, are shown in Table 12. Certainly, inferences drawn from this one set of samples can only be of a very preliminary nature. Even so, several points appear to be worthy of note.

(1) Nitrogen content is affected very materially by fertilization and there appear to be differences in nutrient content between the grasses. Dune panic grass was substantially higher in phosphorus and potassium than American beachgrass but similar in nitrogen content where the two grasses were growing together (see footnote in Table 12).

TABLE 10
Seasonal Distribution of Chemical Composition of American Beachgrass - Hatteras Island 1965

<u>Date of Harvest</u>	<u>Yield lb/acre</u>	<u>Chemical Percentage</u>						<u>Boron (ppm)*</u>
		<u>Nitrogen</u>	<u>Phosphorus</u>	<u>Potassium</u>	<u>Calcium</u>	<u>Magnesium</u>	<u>Sulfur</u>	<u>Sodium</u>
April 22	118	2.96	.16	1.42	.35	.13	.10	.32
May 12	286	2.60	.12	1.95	.50	.16	.11	.25
June 3	503	1.89	.07	2.03	.49	.11	.05	.35
June 23	726	1.54	.08	1.59	.39	.09	.06	.26
July 9	843	1.35	.09	1.44	.36	.08	.04	.17
July 22	1126	1.13	.12	1.36	.37	.09	.05	.29
August 13	1694	1.06	.11	1.32	.36	.11	.03	.20
August 26	1984	1.17	.12	1.28	.49	.14	.05	.21
September 8	2416	1.29	.13	1.30	.50	.16	.08	.52
September 28	2143	1.47	.12	1.18	.61	.17	.08	.30
October 13	2473	1.32	.11	.95	.41	.12	-	.20

*Parts per million

TABLE II
Seasonal Distribution of Chemical Composition of American Beachgrass - Ocracoke Island 1965

Date of Harvest	Yield lb/acre	Chemical Percentage						Boron (ppm)*
		Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur	
April 21	71	2.87	.19	1.26	.29	.15	.11	.52
May 12	189	2.60	.12	2.19	.33	.15	.10	.32
June 3	489	2.01	.08	2.25	.34	.13	.05	.46
June 25	1139	1.31	.11	1.66	.35	.10	.04	.19
July 9	1466	1.43	.10	1.66	.34	.12	.06	.21
July 22	1970	1.23	.10	1.68	.29	.12	.05	.20
August 13	2815	1.02	.10	1.26	.28	.17	.04	.24
August 26	3222	1.20	.09	1.32	.31	.16	.04	.23
September 10	3289	1.17	.09	1.24	.29	.15	.05	.25
September 28	3405	1.24	.10	1.19	.33	.13	.06	.29

*Parts per million

TABLE 12
Chemical Analyses of Dunegrass Plants - Summer - 1965

Site No. Species	Initiated Treat.	Fert.	Chemical Percentage						Boron Yields (ppm) lb/acre
			Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sulphur	
1 American Beachgrass	9/1961	0	1.12	.16	.64	.20	.21	.06	.53
		N	1.78	.14	1.03	.26	.14	.04	.44
		NP	1.74	.21	.97	.29	.16	.06	.47
		NPK	1.83	.22	1.77	.32	.16	.04	.30
2 American Beachgrass	9/1962	0	1.02	.16	.81	.21	.18	.06	.41
		NP	1.07	.15	.71	.22	.15	.04	.50
3 American Beachgrass**	9/1962	0	1.05	.13	.69	.28	.17	.07	.53
		NP	1.92	.13	.71	.46	.16	.10	.96
		NP*	1.76	.14	.70	.39	.14	.08	.54
4 Cordgrass	9/1961	0	.55	.10	.59	.39	.40	.19	1.28
		N	1.00	.06	.76	.40	.24	.14	1.39
		NP	1.01	.12	.68	.41	.27	.16	1.55
		NPK	1.16	.12	.91	.38	.24	.18	1.49
		N*	.75	.05	.76	.39	.18	.15	1.00
		NP*	.71	.09	.67	.27	.20	.12	1.22
		NPK*	.64	.12	.68	.39	.17	.12	.48
5 Cordgrass	3/1962	0	.73	.07	.54	.41	.16	.16	1.07
		NP	.80	.07	.56	.36	.18	.20	1.02
6 Cordgrass	9/1962	0	.88	.16	.68	.43	.31	.13	2.00
		NP	1.21	.11	.54	.58	.27	.09	1.60
7 Sea Oats	4/1964	0	1.21	.20	.75	.26	.21	.12	.28
		NP	1.86	.15	.71	.26	.17	.08	.38
8 Dune Panic Grass	4/1964	0	1.43	.26	1.62	.40	.19	.06	.22
		NP	2.34	.25	1.51	.60	.34	.11	.41
3 Dune Panic Grass**	9/1962	0	1.33	.24	1.58	.41	.23	.08	.33
		NP	1.82	.22	1.10	.53	.28	.09	1.18

*Discontinued fall, 1964. **American beachgrass and dune panic grass growing in a mixture on same plots.

(2) Cordgrass tends to be lower in both nitrogen and phosphorus than the other three grasses and this seems to hold for both fertilized and unfertilized plants.

(3) Based on the single site sampled, the sea oat is fairly high in nitrogen but not very different from the other grasses in the content of the remaining constituents reported.

(4) There does not appear to be any very definite pattern in the other constituents except that cordgrass tended to be high in sodium and to a lesser degree in sulphur. This could well be a site difference since this species is grown only on the lower, wetter locations where sodium is probably more plentiful and organic matter slightly higher.

(5) These analyses tend to be in agreement with the growth response data in suggesting that nitrogen is the principal limiting factor on the growth of those grasses in this environment. The data also suggest that for this stage of growth (early summer), the critical level of nitrogen in the plant might be around 0.75 percent for cordgrass, 1.00 percent for American beachgrass, and probably near 1.25 percent for dune panic grass and sea oats.

e. Micronutrients

Two replicated trials were established in the spring of 1965 on stands of American beachgrass which were planted in January 1965. One of these was located on hydraulic fill and the other on windblown sand. The treatments involved Manganese (Mn), Copper (Cu), Zinc (Zn), Iron (Fe), Boron (B), Sulphur (S), and combinations of these. All plots received the standard treatment of 30-10-0 (125 pounds in April, June, July and September).

There were no significant differences in growth at the end of the first growing season in either of these trials. This is probably not surprising in view of the perennial nature of this species. The trials are being continued.

6. NURSERY PRODUCTION OF PLANTING STOCK

The production of planting stock for experimental plantings has been carried out cooperatively with the Forestry Division, North Carolina State Department of Conservation and Development at the Clayton nursery. Research on this phase has been very limited, to date, but some things learned through this experience are worth repeating here.

a. American Beachgrass

Plantings of this species were made at Clayton in the spring of 1962. These consisted of (1) about 1 acre of single stems spaced 20 x 34 inches and (2) a 4 x 500-foot bed seeded with 1/2 pound of seed. Both of these were successful with about 33,000 three-stem plants being harvested

from the acre planting during the winter of 1962-1963, and about 60,000 three-stem plants from the seeded bed. Tests the following year indicated that plants produced in either manner were equally satisfactory when transplanted to the dunes.

It was concluded, however, that for nursery establishment, vegetative propagation was more practical than propagation by seed due to the weed problem. Quite satisfactory control can usually be obtained in vegetative plantings with one early spring application of weed killer, while seeded beds must be fumigated.

Although all of the planting stock was harvested from the original nursery planting in the winter of 1962-1963, the rhizomes remaining in the soil resulted in a solid stand the following year. It appears that a full harvest of planting stock can be expected each year from a nursery area of this kind, provided adequate fertilizer is supplied and weeds are controlled. Where planting stock is not harvested for a year or two, the buildup of dead material makes processing difficult. For this reason it may be cheaper to start over on a new area every second or third year.

This grass appears to tolerate a fairly wide range of soils and present information seems to be adequate for outlining procedures for practical and rather inexpensive nursery production.

b. Sea Oats

As recently as 10 years ago, reputable scientists were saying that sea oats did not produce viable seeds. This observation apparently arose from the fact that sea oat seeds usually have a very pronounced dormancy period. However, seedlings have been observed occurring naturally on the Banks for several years, and in 1964, Wagner (7) published the results of a study in which he followed the germination of sea oats in some detail both on the dunes and in the greenhouse.

In the winter of 1963-1964, we undertook some limited tests on seed harvested in the fall of 1963. After trying several of the conventional procedures for breaking seed dormancy, it was found that a fair response could be obtained by soaking the threshed seed overnight in a gibberilic acid solution of 100 parts per million. Using this procedure, two beds were seeded in the nursery in April 1964 and several thousand plants were produced.

Unfortunately, growth in late summer was hampered materially by an attack of a "helminthosporium-like" organism, as yet unidentified. This was followed during the winter by damage from billbugs and a stem maggot similar to the Hessian fly. Plants transplanted to the Banks in December and January survived and grew well; later transplants having more insect damage did not do as well.

A few hundred plants were separated and transplanted into nursery rows in the spring of 1965. Although survival was poor due to the previous

insect damage, those that survived grew well. Other plants were left in place in the nursery bed and these multiplied quite well but were not as productive as the transplants.

In the meantime, Westra (8) undertook a fairly intensive study of seed dormancy in this species which he completed in the spring of 1965. Working only with 1964 seed, he found that these were not very responsive to gibberilic acid. We rechecked this in February 1965 with 1963 seed that had been held in cold storage, and found that the 1963 crop was still responsive to gibberilic acid and several thousand more seedlings were grown in the nursery during 1965 following this treatment.

Westra found 1964 seed to be somewhat responsive to thiourea but obtained the best germination from a pre-chilling treatment followed by high or alternating high and low temperatures.

A fairly laborious, but quite successful, procedure that was tried in 1965 involved starting seedlings in the greenhouse and transplanting to the Banks. Gibberilic acid treated seed were planted on February 27, 1965 in small peat pots (2½") in the greenhouse. By May 5, 1965, the seedlings had emerged and were about 7 inches high. At that time the pots were transported to the Banks and planted in the conventional manner. These plants grew off much more rapidly than seedlings from direct seedings either on the Banks or in the nursery. For example, plants from direct seedings that we have observed on the Banks have never developed more than 2 or 3 stems (culms), and usually only 1, by the end of the first growing season. These peat-pot plants developed vigorous crowns which contained an average of 13 stems (some as high as 30) per plant by August 18 of the first year.

While a great deal remains to be done on this problem, present knowledge makes nursery production of planting stock of this species a practical possibility. Acceptable germination on most seed lots should be attainable with one or the other of the alternative treatments available. In most cases preliminary trials will be needed to determine the effective treatment for any given lot of seed. It is apparent that dormancy in sea oats is quite variable, both between years and between lots of seeds of the same year. Once sea oat seedling plants are available, they can be multiplied by division as with American beachgrass, although production seems likely to be a good bit slower.

c. Dune Panic Grass

This grass is very readily multiplied under nursery conditions. Stands may be established by burying stems and rhizomes in furrows or by broadcasting the material on the surface and covering it by disking.



Figure 9. First Year Growth of American Beachgrass. North Carolina Forestry Nursery, Clayton, N. C.



Figure 10. Sea Oat Seedlings in August Following Direct Seeding in March. Ocracoke Island.

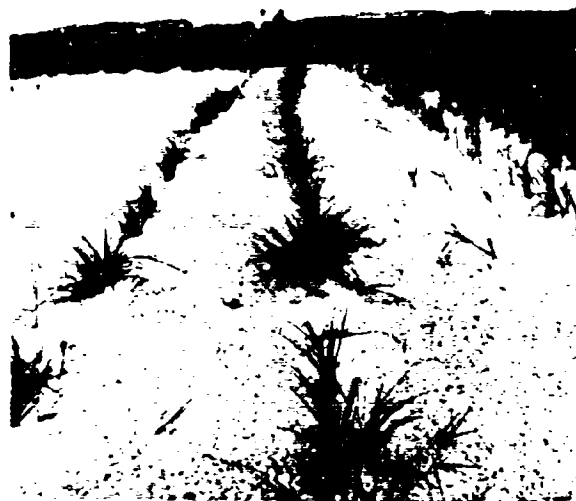


Figure 11. Sea Oats, First Year After Transplanting from Nursery (2 Rows Center and Left) - Ocracoke Island.

7. PLANTING METHODS

a. Date of Planting

American beachgrass seems to have a fairly wide tolerance to date of planting. The experiment reported in Table 13 was carried out to get some more precise estimates of this tolerance.

TABLE 13

Date of Planting - American Beachgrass - Hatteras Island

<u>Planting Date</u>		<u>Yield lb/acre</u>
		August 15, 1965
October 14*	1964	530
November 12	1964	1010
December 23	1964	976
January 12	1965	1124
February 16	1965	816
March 18	1965	821
March**	1965	935
April 15	1965	605
April**	1965	648
May 11***	1965	513
Least Significant Difference .05		122
Least Significant Difference .01		164
Coefficient of Variability		46%

*Plants not nursery grown, dug on dunes and replanted immediately.

** Plants dug December 15, 1964 and stored at 34-38° F. until planted.

***Plants dug March 19, 1965 and stored at 34-38° F. until planted.

All others dug from nursery and planted within one week.

From this one-year experience, it appears that the planting date has no major effect on first-year growth from the time dormancy begins (around November 1-15 at this latitude) until new growth starts (around March 15). Plants were not fully dormant on October 15 and plants dug and replanted at that stage did not grow off nearly as well as those transplanted a month later. Plantings made after March 15 were also at a disadvantage. It is significant that survival was nearly perfect at all dates, indicating that, in the less critical situations, the planting season could begin as early as October 15 and be extended as late as early May. However, where full growth is desired, November and March seem to represent the limits.

It had been thought that it might be possible to dig plants during the dormant period, hold them in cold storage, and, thereby, extend the planting season. This appeared to have some advantage during the first few weeks after planting, but as the season progressed, most evidence of it disappeared. This point may deserve further study.

Time of planting other species has not been studied experimentally. Observations suggest that it may be desirable to transplant sea oats and perhaps dune panic grass in late fall soon after they become dormant. Cordgrass can be transplanted later in the spring than beachgrass, even into the summer, on wet flats.

b. Number of Stems - American Beachgrass

It has been customary in this area in planting American beachgrass to use plants composed of 3 to 5 stems (culms) in each planting hole or hill, and this practice has been producing satisfactory stands the first year. Obviously, planting stock represents a significant part of the total cost of planting. For this reason, trials were set out in the early spring of 1964 and again in the winter of 1964-1965 to examine the effect of number of stems on first-year stand and growth.

Plants of different sizes were obtained in two ways (1) single stems - the nursery clone broken down to single stems and these recombined to get the desired number in each hill, and (2) clumps - the clone was divided into intact plants of different sizes, i.e., 1, 2, 4, 8 and 16 stems. Data from these tests are shown in Table 14, and an average of the two 1965 tests plotted in Figure 12.

The effect of number of stems is quite consistent throughout these trials, indicating that this variable has a major effect on the cover produced by a given planting through the first growing season. This would suggest that adjustments in number of stems per hill depend upon the objective of the particular planting, the nature of the site, and the rate of growth expected. Single-stem plants may be justified in plantings on unexposed areas where little blowing sand is likely to be available. Certainly, in more exposed locations and where the object is to trap blowing sand, much larger plants would be highly desirable.

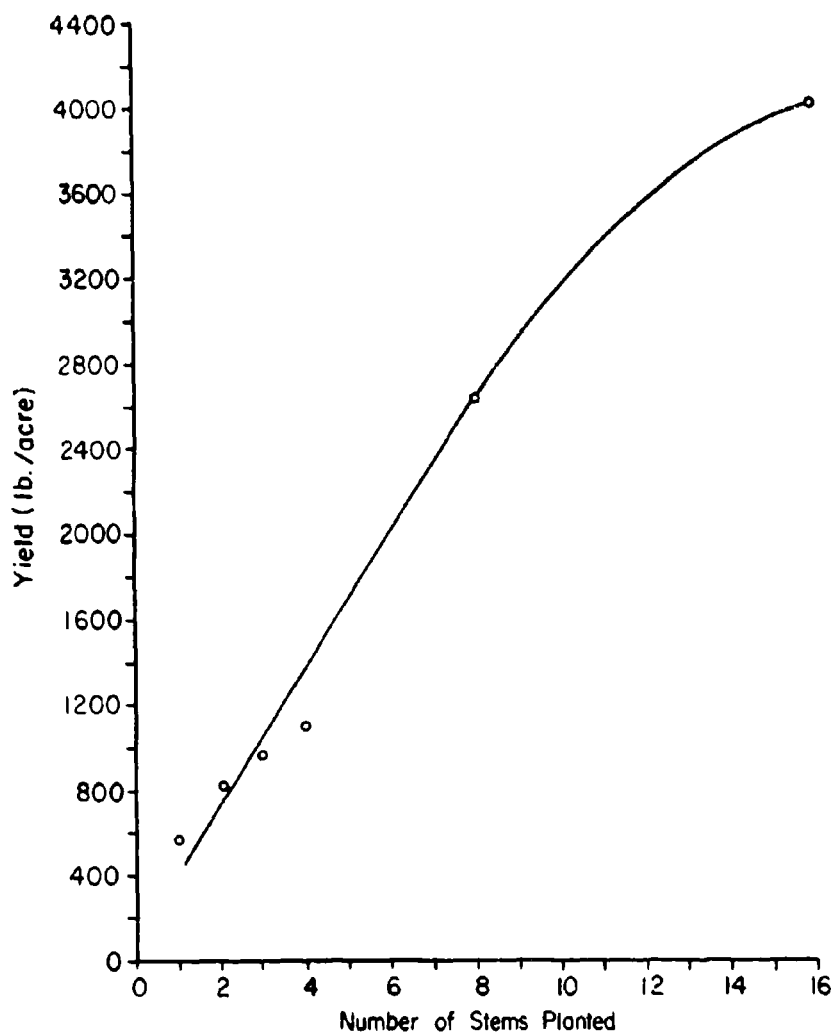


Figure 12. Effect of Number of Stems per Hill on First-Year Growth of American Beachgrass - Average of two sites

TABLE 14

Effect of Number of Stems per Hill, First-Year Growth
American Beachgrass

Stems per Hill	Yield lb/acre end of August, First Year					
	Planted late March, early April 1964, 18" Spacing		Planted February 1965			
	Dune Sand		24" Spacing		18" Spacing	
	Ocracoke Island		Dune Sand		Hydraulic Fill	
	Single	Clump	Ocracoke Island	Single	Hatteras Island	Clump
1	542	444	661	576	605	519
2	768	640	1072	880	836	590
3	-	-	1115	1093	1030	792
4	1080	931	1344	1280	1282	821
8	1462	1380	3686	3585	1995	1664
16	2468	2502	5632	5581	3291	2262
Least Significant Difference .05	405	405	156	156	-	-
Least Significant Difference .01	552	442	212	212	-	-
Coefficient of Variability	57%	57%	60%	60%	-	-

There was a small but consistent difference in both of the 1965 trials favoring breaking plants down to single stems versus planting clumps. This difference is relatively small, but it certainly suggests that the single stems that normally turn up during processing are not undesirable.

Under adequate fertilization and assuming that the stand survives the first season intact, it is likely that the number of stems per hill is much less important in succeeding years.

More data on the effect of plant spacing on sand trapping will be required to make possible the computation of optimum planting density for various situations. Experiments covering these points are underway. Very effective sand trapping, however, has been obtained with a first-year growth of around 1200-1500 pounds of dry weight per acre. Preliminary indications are that efficiency falls off fairly rapidly as cover becomes thinner than this.

These data appear to be in direct contradiction to data recently reported (2) from a trial in Delaware, in which single stems were found to be equal to two-stem and three-stem plants. We are at a loss to explain this difference unless the low rate of fertilization (2/3 of the plots received 40 pounds nitrogen per acre or less) was the principal limiting factor in the Delaware trial. It is impossible to compare level of production of the Delaware and North Carolina trials since the Delaware results are reported in number of stems (culms).

c. Topping

Removal of a portion of the leaf area of beachgrass plants, prior to planting, could be desirable to reduce excessive transpiration and wind whip. A planting made in March 1964 and two others planted in January and February 1965 tested this practice. See data in Table 15.

These data indicate no advantage for pruning in either survival or regrowth. This is not surprising since the observed normal pattern is for planted tops to die back to the sand surface shortly after planting with essentially all regrowth emerging as new shoots from base of the plant.

Two other points should be weighed in connection with pruning. With very large plants, there is a distinct advantage in pruning some excess growth to facilitate transport and handling. Pruned stock is easier to get through a planting machine. On the other hand, where blowing sand is available, unpruned tops often trap substantial amounts of sand before new growth emerges in the spring. In critical areas this will, at times, save plants that would otherwise have been blown or washed out before they can become established.

TABLE 15

Effect of Planting Method on First-Year Growth of American Beachgrass

	1964 lb/acre (2 Replications)	1965 lb/acre (3 Replications)	
	<u>Dune Sand</u>	<u>Dune Sand</u>	<u>Hydraulic Fill</u>
Pruned:			
Topped to average length or 15" (about 1/3 of above-ground portion of plant removed).	629	1146	980
Pruned and furrow planted:	-	954	1076
Furrow 6 to 8" deep.			
Unpruned:			
Normal planting	664	1364	989

d. Erect vs. Horizontal Planting

The established practice has been to set planting stock in the same erect position used in transplanting tree seedlings or tobacco. All available planting equipment is designed to plant in this manner. In the two 1965 tests shown in Table 15, a treatment was included which involved planting pruned stock horizontally in a furrow. In both tests there was little difference in total first-year growth between this method and the normal method. During the growing season, the furrow method actually produced more new shoots per row, but total growth was not increased since many were slower in emerging. With horizontal planting, many of the new shoots emerged from nodes which were located various distances from the base but kept moist by covering in the furrow.

This finding would indicate that there is considerable latitude in positioning planting stock of this species, and if furrow planting were better mechanized, burying the plants deeper than is now practiced would be permissible.

e. Clay Dip

For some time the Forest Nursery has dipped the roots of tree seedlings in a clay slurry prior to packaging and shipping to prevent dessication. This method was tried on beachgrass planting stock, planted at several locations in the spring of 1963. Where conditions were favorable, there was no apparent benefit, but on Bodie Island, under very dry conditions, the clay dip was highly beneficial. Consequently, clay dip was adopted for all planting stock as insurance against poor planting conditions or careless handling of plants prior to planting. It is quite inexpensive and can occasionally mean the difference between success and failure.

f. Thinning

One small trial, 2 replications, was established 12 January 1965 to study the effect of thinning existing stands of American beachgrass to obtain planting stock. This was done on a two-year-old, machine-planted stand that had been well fertilized. The treatments consisted of pulling by hand varying portions of the standing clumps as described in Table 16.

From this one trial, it appears that removal of planting stock from a vigorous well-fertilized stand of this grass has little or no effect on regrowth the next season. As under nursery conditions, the rhizomes left behind are able to completely replenish the stand. However, it should be remembered that this practice does temporarily deprive the area of cover. Also, weak or unfertilized stands would be very unlikely to restore themselves so readily under such treatment.

TABLE 16

Effect of Thinning on Regrowth of American Beachgrass

<u>Amount pulled 12 January 1965</u>	<u>Yield, lb/acre 15 August 1965</u>
1. None	3985
2. 50% - every other clump	2965
3. 50% - 1/2 of each clump	3253
4. 67% - 2 of every 3 clumps	3151
5. 100% - all	3217
Least Significant Difference	Not significant
Coefficient of Variability	43%

g. Direct Seeding of Sea Oats

There is considerable interest in direct seeding of sea oats and other species on the Banks with the hope that a substantial reduction in planting costs might follow. Since the sea oat has been observed to spread rather extensively by seed at times, it was chosen as the best plant for the first trials of this kind. A number of seeding tests of an exploratory nature were initiated in the winter and early spring of 1964-1965. Some of these were successful to the extent that stands of seedlings were obtained. While these tests did not add greatly to our knowledge on this subject, they did point up some of the problems involved:

(1) Temporary stabilization - it is necessary to avoid substantial sand accumulation or loss within a seeded area at least until seedlings have emerged. Indications are that successful germination and emergence are likely to occur only from within a zone from 2 to 6 inches below the surface. Frequent drying of the surface 2 inches prevents germination at the shallower depths; food reserves probably limit emergence from zones more than about 6 inches below the surface.

(2) Since two growing seasons are usually required for full establishment of a sea oat seedling, direct seeding is not likely to be useful on the more critical areas.

(3) Further studies will be needed to determine optimum pretreatment, seeding dates, seeding depths, etc., to insure early emergence of seedlings. Since the sea oat seedling grows off quite slowly the first season, early emergence is likely to be very important to survival.

(4) Direct seeding presents some possibilities which are worth exploring, but at this point it seems likely to supplement rather than replace vegetative planting on most dune and beach areas.

8. IMPROVED STRAINS OF AMERICAN BEACHGRASS

The fact that American beachgrass apparently was not native to the North Carolina coast would seem to make it particularly appropriate to look for strains within the species that are better adapted to this area than others.

Considerable variation in plant type was observed in the 1962 nursery planting of this species. Consequently, 18 clones were selected from this material in the winter of 1962-1963, encompassing a wide range in stem size, rhizome production, and general vigor. These were multiplied in the nursery, and nine were transplanted to the Banks in replicated strain tests in the 1964-1965 planting season. Although at least another year or two will be required to fully evaluate these tests, there are four selections which, so far, appear to stand out in vigor and rate of spread. These will probably be put in increase plots this winter to provide material for larger scale tests in the future.

It is much too early to say that any of these selections are superior for North Carolina conditions, but at this point some of them appear quite promising.

9. DUNE BUILDING

The "growing" of natural dunes along the coast as a result of vegetation trapping blown sand has been observed by many, yet little seems to be known about this process. Since foredunes must be stabilized in order to be effective, and since planting of such areas is often difficult due to their rough nature and steep slopes, it seemed desirable to explore "growing" planted dunes. In March 1964 on Ocracoke and on the Core Banks, trial plantings were established in areas devoid of foredunes. Cross sections taken in July 1965, about 15 months after planting, showed the accumulation of as much as 16 cubic yards of sand per running foot of beach for a planting of American beachgrass 100 feet in depth. Since each planting was only about 100 feet long, it was exposed to blowing sand from all sides. This would tend to exaggerate the estimate of the amounts of wind-blown sand available in the area but should still give a realistic figure for capacity of the planting to trap sand.

Following these trial plantings, more formal and much more extensive tests were initiated on Core Banks and Ocracoke Island in the winter of 1964-1965, and those on Core Banks were further expanded in 1965-1966. It is too early to report on these trials, but it may be noted that they include such variables as plant spacing, number of stems per hill, width of planted strip, sand fences, and American beachgrass versus sea oats. Preliminary results appear promising for the general objective, i.e., "growing" stabilized dunes.



Figure 13. An Unusually Vigorous Strain of American Beachgrass (Center 4 Rows). Photo taken near end of first growing season after transplanting to the Banks. Note new plants emerging between rows.



Figure 14. Machine Planting of American Beachgrass, Using 2-Row Planter - Core Banks, November 1965.



Figure 15. Unplanted Section
4-foot Sand Fence, Full, 8
Months after Installation -
Ocracoke

Figure 16. Section Planted 25
Feet wide to American Beach-
grass with 4-foot Sand Fence
Installed on the Front. Photo
8 months after planting.



10. GENERAL EXPERIENCE

a. Fertilizing Large Areas

The National Park Service initiated a fertilizer program at Cape Hatteras National Seashore in the spring of 1963 based on the results of the preliminary trials conducted in that area in 1961 and 1962. Primary attention in this program was focused on the zone comprising the foredune and a strip, one to three hundred feet in width, behind the foredune. This involved a total area of about 2,000 acres, spread over a length of 65-70 miles.

A 30-10-0 fertilizer compound, developed and supplied by the Tennessee Valley Authority, was chosen as the most suitable material available. The principal considerations were: a pelleted material, supplying nitrogen and phosphorus with a high nitrogen to phosphorus ratio at a reasonable cost. The program through the three years from 1963 to 1965 consisted of four applications per year of 100 to 125 pounds each of the 30-10-0 material, applied around April 1, May 15, July 1 and September 15.

Application by helicopter turned out to be a very satisfactory method. The principal advantages are:

- (1) Much better distribution than could be attained with ground equipment over this rough terrain;
- (2) absence of damage to dunes which would result from ground equipment;
- (3) ability to operate satisfactorily under the prevailing windy conditions; the down-blast from the rotor blades drives the pellets downward with considerable force;
- (4) flexibility in landing requirements which always permits loading close to the area to be fertilized, and
- (5) reasonable cost - of the order of \$2.00 to \$3.00 per acre, per application.

This very satisfactory 3-year program resulted in a "full cover" condition on perhaps 90 percent of the area by the end of the third growing season. Three years earlier, about 90 percent of the area consisted of thin degenerating stands. Generally, the areas that still lack adequate cover are those that carried very few plants at the beginning of the program or have only recently been planted. Fortunately, this stretch of the Banks has not been subjected to hurricanes or other exceptionally severe storms during this testing period, thus permitting the uninterrupted development of the cover. The value of this greatly improved cover remains to be tested by storms, but there is every reason to expect substantial benefits. One, already obvious, is the noticeable gain in elevation of many areas due to the trapping of sand by the improved cover. With the attainment of "full

cover" on most of the area, the fertilizer program should be reduced to a maintenance level, except on the occasional weak spots. Data are not yet available to define the exact form this maintenance should take, but as a first approximation, a cut-back to one annual application of 30-10-0 seems reasonable.

b. Planting

Close to one million hills of American beachgrass plus a few thousand hills of sea oats have been planted during the past 2 years in our experimental program. Some have been hand-planted, but most have been planted with a conventional 2-row transplanter commonly used for transplanting such crops as tobacco. The only modification required is that the openers, or shoes, should be extended to provide a furrow 8 or 9 inches in depth. A wheel-type farm tractor is adequate as a power source on fairly smooth areas. It is important that such machines have adequate weight and power to operate the planter in a "no strain" condition. Our experience indicates that with such equipment, and under good planting conditions, a crew of six men can plant around 20,000 to 30,000 hills per 8-hour day.

Small crawler-type tractors have been used as a source of power by the National Park Service and also by contractors on the hurricane protection project at Carolina Beach. The Park Service has also used a wheel-type tractor equipped with a half-track attachment. These operate on steeper slopes than the wheel-type machines but it has been necessary to switch over to hand planting in cases when slopes get much steeper than 1 on 5.

II. RECOMMENDED PRACTICES

a. American Beachgrass

(1) Planting dates. November 1 to April 1 - later planting, to May 15 is feasible if planting stock is dug while still dormant and held in cold storage (34° to 38° F).

(2) Plants. Plant 3 to 5 stems per hill; single-stem plants can be used on protected sites where first-year growth is not important.

(3) Spacing. Plants should be spaced 18 x 18 inches (about 20,000 plants per acre) on very critical areas. However, preliminary indications are that spacing 24 x 24 inches (about 11,000 plants per acre) may be sufficient in most cases, provided vigorous growth is assured by timely planting and adequate fertilization.

(4) Planting depth. Plant so that base of plant is about 6 to 8 inches below the surface. Firm sand around base to avoid excessive drying and to anchor the plant against the wind.

(5) Fertilization. First year - apply total of 150-200 pounds of nitrogen and 50-60 pounds P_2O_5 per acre, divided into four equal applications around April 1, May 15, July 1 and September 15. (This maintenance may be

obtained from 30-10-0, where available, or approximated by applying a mixed fertilizer containing nitrogen and phosphorus at the first application and straight nitrogen materials for the remainder.)

Second year - follow plan suggested for first year, except where first-year growth is especially good, it may be advisable to drop back to two applications, the first around April 1 and the second around September 1-15.

Third year and thereafter - apply April 1 treatment as described above and adjust up or down as growth warrants. One application in alternate years may be sufficient on some sites while more than one per year may be needed on others.

b. Sea Oats, Saltmeadow Cordgrass, and Dune Panic Grass

These grasses are just as responsive to fertilizers as American beachgrass, and much the same fertilization scheme is suggested for them. Since these are warm-season grasses, the first application in the spring should be 2 or 3 weeks later, and summer applications may be more important. Information is too limited to make specific suggestions on planting procedures, spacing, etc., at this time, but in general it appears that they can be handled in much the same manner as American beachgrass. Saltmeadow cordgrass should be planted only on the low, relatively moist, sites, not on foredunes.

c. Planting Location of All Grasses

Bare areas anywhere above the high tide line can usually benefit from vegetation. In areas exposed to the surf, vegetation is effective only above the level of mean high tide. Vegetative cover will not withstand constant wave action. However, dense grass cover does provide substantial protection against damage from storm tides where the wave action may be quite intense but of relatively short duration.

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